

# BUILDING A BUSINESS CASE FOR MODELING AND SIMULATION

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Modeling and simulation technology is the use of models to develop data as a basis for making managerial or technical decisions. It can be a valuable tool for program managers—but it is one that is vastly under-used. This article provides a business-case framework (a methodology to evaluate investment opportunities) for program managers within the Department of Defense to use when determining how to apply modeling and simulation in project management.

**T**he use of modeling and simulation (M&S) is widely misunderstood within the Department of Defense (DoD). M&S is the use of models, either statically or over time, to develop data as a basis for making managerial or technical decisions (DoD, 1997). Models are physical, mathematical, or logical representations of a system, entity, phenomenon, or process. Simulations are methods for implementing models over time. Normally, we associate simulations with a software program that implements models over time, within the context of a given scenario (Defense Modeling and Simulation Office, 1996). Simulations permit the user to assess variables and the predictability of a single or series of outcomes.

Nowhere is the misunderstanding more painfully obvious than within the program management offices of the DoD. Some program managers believe M&S is paramount to effective project development and place the requisite investment in it (and this article highlights examples of some such programs). But many program managers remain both skeptical and suspicious. Recent government direction to use simulation-based acquisition in DoD programs is an example of a policy with good intentions but poorly shaped execution. This edict has been met with, at best, marginal acceptance, and at worst, abject resentment.

Such resentment and apprehension spring from institutionalized biases,

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including DoD funding procedures, that work against optimizing the potential gains of employing modeling and simulation. By far, the severest criticisms targeted at M&S center on the debate over return on investment (ROI). As we will discuss later, ROI is just one of many techniques in evaluating the use of M&S in a program. Ostensibly, DoD has accepted this new technology as a means of reducing costs, increasing cost avoidance, and banking the residual benefits for other projects.

Many program managers argue that the entire acquisition system is focused on getting a project into production, through performance trials, and permanently into the military's inventories. Seldom are they

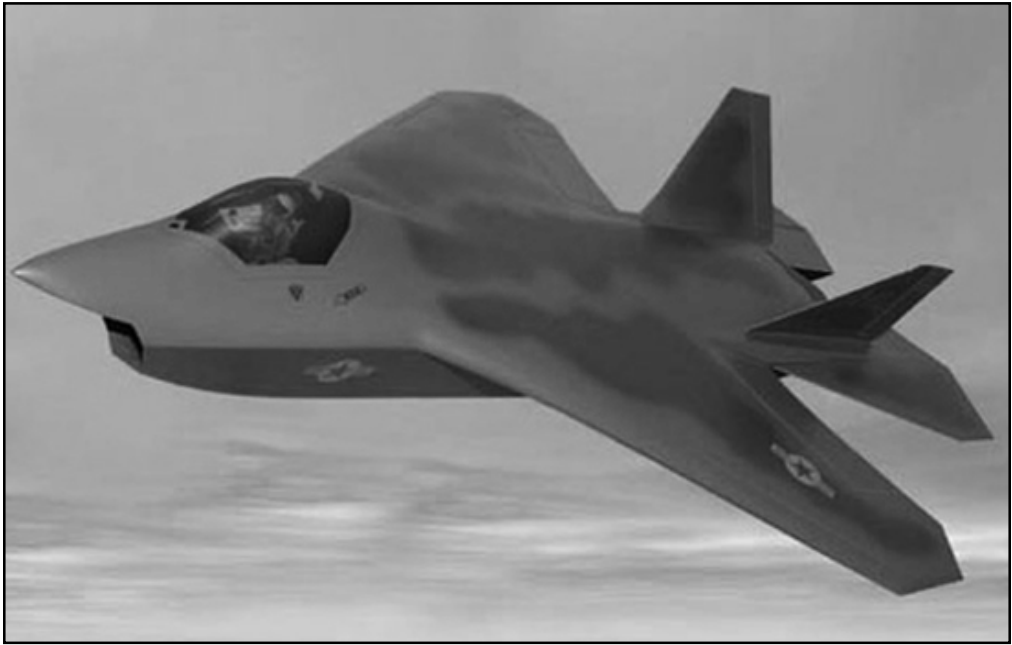
"Simply put, program managers are under intense pressure to complete their programs on or under budget and within timelines."

given sufficient funds, staff, or time to investigate the potential benefits of tools or technologies such as M&S. Importantly, leadership provides little in-

centive to capture data, build expensive models, or conduct additional analyses to transfer M&S results to other projects. Simply put, program managers are under intense pressure to complete their programs on or under budget and within timelines. Existing programs lack enticement to develop new models or simulation tools that may have wider application to other programs, or that will be much cheaper to operate and sustain. With few exceptions, these occurrences were more a result of coincidence than deliberateness.

Finally, perhaps the greatest impediment to M&S acceptance is lack of knowledge. Many people do not understand the potential benefits of this technology, or how to define needs and produce the right tools that will help the project. Unfortunately, this reticence may be reinforced by an institution which neither favors nor rewards risk takers. Sometimes, a program manager may not know for certain if a major investment in M&S is warranted. If a program manager wants to invest in the technology "just to see if there is a benefit," he or she faces criticism if the results are not positive. Thus, a program manager must weigh the costs of the risk, and consequently few take the chance, preferring more traditional approaches—the building of expensive mock ups; the use of labor-, time-, and money-intensive trials, and incurred costs of waste.

The deputy project manager (DPM) of the Joint Strike Fighter (JSF) praised the future of M&S while lamenting the military's reticence to embrace it. "The Joint Strike Fighter Project achieved immeasurable benefits from its innovative use of modeling and simulation. More important, I was impressed with the tremendous intellect and drive of many of the staff who were willing to try new models. They did simulation runs—sometimes up to 1,000, in order to bring this project along a development path to bring the necessary technology-enhanced fighter into the 21<sup>st</sup> century. They took the risks and it's paying off" (1999).<sup>1</sup> The DPM made this blunt statement—"No high-tech project will achieve any significant success if it does not incorporate M&S. However, we in DoD just aren't ready to capitalize on this technology."



Joint Strike Fighter

While all of this bodes well for an anecdotal argument supporting M&S, what's needed is a more reasoned and defensible process for determining M&S investments. While few refute the intuitive benefits of M&S, program managers quite rightly argue that any tool must be first measured against its potential benefits before it is used. For example, given that Boeing spent \$2 billion on M&S for its 777 airplane, are comparable levels of investment affordable to program managers of programs of similar magnitude? Obviously, the question is not easily answered. It depends on a variety of factors, including the project's funding, period to recoup the investment, and perceived benefits to developing and using M&S in the program. The crux of the problem is the dilemma of costs versus risks and the potential return. Program managers need

a methodology to evaluate investment opportunities.

## **METHODOLOGY AND APPROACH**

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The authors reviewed selected M&S efforts within civilian industry and DoD. We visited several key manufacturing and service industries, which were also wrestling with the same subject—the assessment of M&S investment. Understandably, each sector had a slightly different motivation or incentive to invest in M&S. One company was concerned about long-term applicability and the transference of technology to future programs. Another was in the business of capturing data and shaping models and the requisite simulation runs to satisfy client needs. They were using training models and virtual reality

technology as a means to reduce training costs and time. Another believes a judicious application of M&S reduces direct manufacturing costs. For example, on the JSF program, simulations are improving mechanical tolerances such that developers project shim stock weight reduction from an average of 40 pounds per aircraft (as is the case with the F-16) down to less than 1 pound. Such projections are reasonable, based on actual data from Boeing 777 design and projection.

While there are some common applications industry-wide, DoD is not focused on profit, but on performance and total ownership costs.<sup>2</sup> We surveyed a large number of DoD program managers, with programs in various stages of the acquisition process. The survey requested general information from the program managers regarding how they made decisions on M&S investments. Additionally, in an effort to maintain balance, we also surveyed several government contractors. We

also conducted a literary search to capture the body of knowledge in non-government organizations related to justifying M&S investments.

### **RESULTS OF SURVEYS**

In general, survey responses indicated that program managers are investing in M&S to support program development; however, most of the investment decisions were based on intuition or need-based factors. Most decisions were made without detailed quantitative analysis. Ostensibly, program managers accepted modest investment in M&S because they believed that it would benefit the program. These efforts, however commendable, lacked a methodical cost-benefit analysis. Additionally, the lack of a structured business case analysis made it difficult, if not impossible, for program managers to articulate or substantiate their investment strategy. In some cases it came down to a program manager wishing to explore M&S

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F16

without knowing what benefits might be achieved. This is not really taking a risk; it is more an exploratory probe into a new field. These program managers were embracing new technology—but without a sound business case approach, they could not really assess if the investment would realize considerable benefits or generate prohibitive costs.

Most program managers justified their M&S investment based on one or more of the following:

- reducing design cycle time;
- augmenting or replacing physical tests;
- helping resolve limitations of funds, assets or schedules; or
- providing insight into issues that were impossible or impracticable to examine in other ways.

Much of the feedback reflected that program managers had tried to examine costs and measure them against benefits—but without the help of any business case analysis format. Consequently, approaches and results varied. Few reported to have used a disciplined approach. The use of inconsistent applications or approaches leads to mixed results that cannot be readily compared or evaluated. The majority of respondents suggested the question of using M&S was not one of “Should I?” but rather, “How can I?” This demonstrates general acceptance that M&S is required in an efficiently managed program. But it begs the question “at what cost?” Indeed, the cost of investment may be prohibitively expensive, or there may be only the most marginal long-term

benefits to the department. In such cases, the decision maker should select from alternatives, be it foregoing M&S, partnership with other program managers to share costs, or leveraging the investment of others. This is not a moot point, given DoD’s fiscal limitations.

Program managers want confirmation that investment in M&S will yield direct savings within their budgets. Considering that much of the benefit of M&S investment is intangible, traditional measurement approaches may not provide an accurate assessment. Additionally, program managers may be understandably too parochial in that, if the return is not significant for their immediate

“ Program managers want confirmation that investment in M&S will yield direct savings within their budgets.”

project needs, they may dismiss these tools. But projects are relatively short-lived—we may very well be missing some of the longer-term residual benefits. While traditionally the benefits of M&S tend to be discussed in terms of return on investment, several alternatives for business case analysis can just as effectively justify M&S investments. The challenge is to define an appropriate strategy and priorities to address the business value proposition.

A disciplined approach and methodology has many benefits. It can help bring the aggregate benefits into focus and strengthen the argument for M&S investment. A business case analysis provides a convenient mechanism for project management. It can be an easy-to-follow, logical thread. It also lays the groundwork for

others to attain information that will help their respective programs. This approach forces a timeline, captures benefits, and enables authorities to decide if the return is worth the pursuit.

## MAKING THE BUSINESS CASE

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Corporate America is taking a methodical approach to investment decisions regarding M&S. Although they are primarily profit driven, they share common maxims of production—such as cost reduction, efficiency, and cost avoidance—to that of DoD. Essentially, a business case will assist the program manager in evaluating which of a number of logical packages of alternatives will best meet the program's objective.

### EXISTING GUIDELINES AND INSTRUCTIONS

The survey revealed that although DoD has issued guidance on this subject, few

"The baseline provides a benchmark from which decisions will be weighed and assessed."

program managers reported that they were following it. DoD guidance on investment guidance is provided by DoD Instruction (DoDI)

Number 7041.3, *Economic Analysis for Decisionmaking*, (1995). Enclosure 3 of the DoDI, *Procedures for Economic Analysis*, provides an insightful overview of methodology, criteria and a discussion of sensitivity analysis (1995). The General Services Administration's *Information Technology Capital Planning and Investment Guide*, (1998), also provides

procedures for economic analysis. Some services may also have supplemental guidance (U.S. Army cost and Economic Analysis Center, 1995).

## A BUSINESS CASE FRAMEWORK

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Given our research, the results of surveys, discussions with industry and our literature search, we recommend a seven-step process for assessing the utility of M&S investments:

- Establish a baseline.
- Establish a vision and direction.
- Quantify the costs and benefits of alternatives/capabilities.
- Evaluate alternatives.
- Conduct sensitivity analysis.
- Develop a migration strategy.
- Monitor the process and continue to assess results through formalized feedback.

### STEP 1. ESTABLISHING A BASELINE

As with many other decision-making processes, the first step is to establish an accurate baseline. The baseline provides a benchmark from which decisions will be weighed and assessed. The baseline should include a clear enunciation of assumptions and constraints. Assumptions are explicit statements describing the present and future environment. They reduce complex situations into manageable proportions. These assumptions normally

provide some comment on the estimated future workload, the useful life of the investment or system, and the period of time over which alternatives will be compared. Assumptions should also discuss sunk costs and realized benefits, but are not included as part of the baseline. Constraints are those factors that limit alternatives. Normally they are expressed in terms of time, finances, institutional or regulatory statutes, or directives and physical plant and assets.

The baseline must identify the “higher-value” portions of a program in order to evaluate the appropriateness of various alternatives. For example, in the case of an aircraft, 75 percent of program hours might be expended on the air vehicle team. On closer examination, one might find that 45 percent of that time goes into airframe design, and of that figure, 90 percent is expended on mid-fuselage development. With this informed examination, the program manager will be better able to allocate M&S spending where it will offer the greatest potential savings or benefits. The baseline must determine these high value areas for effective business case analysis. These program specifics form the drivers to the program, which in turn drive the investment process.

## **STEP 2. ESTABLISHING VISION AND DIRECTION**

One must look to the future, then bridge the gap between present knowledge and that required to make future products a reality. A program manager must establish the program’s vision. As with other technologies, the program manager’s vision should consider how M&S tools can improve program costs, scheduling, and performance, and whether scientific knowledge exists to support such M&S

investment. The vision should drive what the M&S tools should be trying to solve, not the other way around.

For example, although the Big Three auto companies in Detroit are producing very similar products, each is using M&S in very different ways, based upon their strategic visions. One is concentrating heavily on using M&S in design at a single location; another is concentrating on moving large amounts of digital information around the world in order to develop a global engineering capability; and the third is heavily investing in reducing the costs of manufacturing. Of course each is doing some or all of these, but the vision provides the focus for allocating their scarce resources. It clearly identifies *what* is to be achieved, without dictating *how* it will be done.

“A program manager must establish the program’s vision.”

## **STEP 3. QUANTIFY THE COSTS AND BENEFITS OF ALTERNATIVES AND CAPABILITIES**

Alternatives are logical packages of initiatives that work well together (Kidwell, 1998). One alternative is the status quo—that is, what we identified as the baseline in Step 1. In some cases the baseline, often a physical test, can be more cost effective than the use of M&S. Other alternatives should represent various combinations of M&S tools that help achieve the vision. In determining alternatives, one must consider both immediate and long-term effects. First, what is it the program needs to perform better? Second, what does the program need in order to survive until the next stage? Most certainly, a

program must satisfy a requirement, but it must also endure and survive each step of the process. It does no good for a program to bankrupt itself with massive unfocused M&S investment early on. Each investment must produce value during a time-frame that is appropriate for the program. Reality requires meeting near-term milestones. The alternatives must also consider the technological advances in M&S tools that might occur. A program might not be justified in spending huge sums of money on M&S technology that will be superseded and rendered obsolete in 2–5 years.

The program manager must identify all costs that are incident to achieving each alternative. Models and simulations can be expensive to develop, particularly in domains where the scientific principles are not fully understood as applied to the problem. While additional research can fill the knowledge voids, the cost of this research must be factored into the analysis of alternatives. These should include

the opportunity costs of assets and resources, which are the alternative value foregone when an asset is used

“Identifying alternatives may be the most difficult portion of the process.”

for other purposes (DoDI, 1995). They also include nonrecurring and recurring costs. Life-cycle costs should include all costs, nonrecurring and recurring, that occur over the life of an alternative (General Services Administration, 1998).

Identifying alternatives may be the most difficult portion of the process. Benefits must be viewed primarily in terms of measurable value. Expected benefits

should flow from the clear operating vision developed in Step 2. Enigmatically, there are both quantifiable and unquantifiable benefits. The former have some tangible or readily identified returns; the latter have less so. Additionally, there may be benefits that have no intrinsic value to one program but provide value to others. We call these external benefits.

**Quantifiable benefits.** These include cost savings, time improvement, acceleration of deliverables, quality enhancement and, in most cases, cost avoidance that is directly related to the program. The alternatives must also consider existing systems and programs. If we are to measure improvements from an “as-is baseline”—we need not start from ground zero. It may be possible for program managers to look at M&S initiatives in other programs, assess their applicability, and leverage them for success. Cost associated with these alternatives should be less, given that a majority of the investment would be a sunk cost borne by others. Similarly, program managers must consider whether partnering with another program, thereby sharing costs, is a possible alternative to reduce up-front investment. Program managers should ensure they have examined all potential benefits by using published references and experts in the field of cost analysis.

**Unquantifiable benefits.** Traditionally, we have considered the issues of risk reduction, organizational efficiency, technology transference, product safety, and environmental impact reductions as unmeasurable and therefore unquantifiable. However, these are important issues, and program managers must consider them in their analysis. To illustrate this point, we will address technology transference.



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The Grizzly

M&S technology transference can significantly influence costs, but in today's DoD environment it has yet to receive adequate attention. Given the shrinking public purse and the demand for greater accountability and responsibility for the dispersal of funds, all program managers must show due diligence in their public spending. They must consider the residual benefits of technology transference.

Some M&S investment might be of use to other projects and program managers. For example, the Grizzly<sup>3</sup> program manager invested heavily in chassis M&S to support short-term design and performance analysis. This M&S investment resulted in \$21 million worth of quantifiable benefits to the Grizzly program. The Grizzly program manager funded the M&S effort through internal reallocation of funds. The program manager's supervisor, program manager Combat Mobility

Systems, recognized the potential for the use of these models for both other program requirements and in other programs sharing the Grizzly's chassis. Program manager Combat Mobility Systems leveraged the Grizzly Program's M&S investment, securing funding to expand the applicability of the initial investment into other programs and to support other long-term Grizzly requirements.

When forecasting near-term savings in design and production costs, one of our surveyed companies accrued substantial unquantifiable benefits. The engineers made a substantial leap in M&S knowledge when learning how to define data needs, how to shape models, and how to refine simulation runs, to narrow the bandwidth of problem solving. The resulting expertise, data, and process could be applied to future projects. Not surprisingly, the company's models and data bank are

the envy of the industry. This was an unquantifiable gain. Another unquantifiable—or at least indiscrete—benefit of M&S is the competitive advantage it provides. This relates back to establishing a clear vision so that early investments will lead the company to where it wants to be in the future.

Unfortunately, many program managers dismiss the concept of unquantifiable benefits. Program managers rarely track these benefits, or those outside the program's realm with any real vigor. They don't afford them reasonable weight when analyzing costs and their alternatives. Similarly, external benefits may exist, not only to service DoD at large, but to external agencies and businesses.

**External benefits.** These are benefits which do not bring direct return or savings to the unique program being managed, but have applicability beyond the

program manager's purse. As mentioned previously, many M&S initiatives and their products can either be modified or di-

"We must overcome the institutional bias that forces program managers to ignore external benefits."

rectly transferred to other programs. Again, looking at the Grizzly program, the contractor supporting the program manager (United Defense Limited Partnership) developed a common product model database that benefited efforts at Aberdeen Proving Ground, The Army Warfighting Analysis and Integration Center, Waterways Experiment Station and National Training Center projects. Thus there is a residual savings for follow-on users. The surveyed program managers did identify

a problem with the high cost of collecting data and maintaining the database. While the cost of performing this might be high, or perhaps even prohibitive to one project, it could be cost effective to several other end users. We must overcome the institutional bias that forces program managers to ignore external benefits. A program manager has no incentive to take on an M&S investment unless he or she can justify the expense from the existing (and often cash-strapped) program. The following example demonstrates how external benefits can show marked savings to DoD and the public.

For years the Aberdeen Test Center (ATC) put vehicles through multiple runs over ground to determine wear and tear on parts and the resultant performance degradation. This required a large number of personnel, vehicles and time to log thousands of miles to achieve statistically significant results. Since then, the ATC completed an intensive project where data was collected describing the complete profile of the course. Subsequently, engineers built the models and now conduct or augment many of these tests on a virtual proving ground using simulations in lieu of hardware. The simulations are so accurate that they have been able to document millions of dollars in cost avoidance for testing of Army programs, while concomitantly helping the Army make the requisite decisions for product and performance improvements. Not surprisingly, others outside the DoD, including private industry, insurance corporations, and the Department of Transportation, also want to use this product. (According to DoDI 7041.3, societal costs and benefits outside the federal government are usually not included in a DoD analysis).

Although this program has universal application, ATC had to offset the costs of this M&S project through internal savings in manpower and overhead, rather than being permitted to share the cost with other programs. An alternative strategy would be to identify potential users in advance and share the developmental costs. Undeniably, program managers should take the first step to accrue direct benefits to their programs. But they continue to bypass transferable benefits simply because direct program constraints preclude further investment of resources.

Perhaps the real value of identifying quantifiable and unquantifiable benefits is in helping others outside the program to realize potential synergies of reuse. For example, the program executive officer, who is charged with program oversight, will have better visibility into requirements and the potential benefits. He or she can more accurately assess M&S investment in relation to a broader sphere of programs. Operational analysis and training are just a few examples. Many of these benefits, while external to an individual program manager, may be internal benefit from the program executive officer's perspective. Armed with this information, a program executive officer may choose to redirect funding from other sources into the program, and/or direct a program manager to take a course of action which may not be cost-effective in a micro perspective; but will bring an aggregate gain that far outweighs the individual investment. But sound management is predicated on program managers providing the program executive officer with data and information drawn from the program manager's business case analysis.

#### **STEP 4. EVALUATE ALTERNATIVES**

We must compare the costs and benefits of each alternative and rank them. Such comparisons must be accomplished using both quantitative and qualitative techniques and criteria. Quantitative techniques include net present value, benefit cost ratio, return on investment, payback method, internal rate of return, hurdle rate, and cost effectiveness analysis.<sup>4</sup> Qualitative

evaluation considerations such as relationship to business strategy, schedule risk, organizational and technical risks, social benefits,

and legal and regulatory requirements may greatly alter the quantitative ranking.

The choice of appropriate tools is program and situation dependent, and can greatly influence the outcome of the analysis. These tools will aid decision makers in accurately evaluating all alternatives such that all costs and benefits are viewed on a level playing field. In general, each feasible alternative, life-cycle costs and benefits, are adjusted using discount factors to account for the time value of money. A complete analysis properly relates quantitative and qualitative factors. Given the importance of these choices, one should seek expert advice and guidance before proceeding.

#### **STEP 5. CONDUCT SENSITIVITY ANALYSIS**

Sensitivity analysis is an essential step in the decision process, as it accounts for ever-present uncertainties. Such analysis repeats the above evaluation of alternatives with changes to the uncertain variables

" Undeniably, program managers should take the first step to accrue direct benefits to their programs."

and examines the effect on the final decision. The outcome will provide a better understanding of the robustness of the output.

Sensitivity analysis is highly recommended, even if there appear to be significant differences among the alternatives, because an apparently superior solution may be very sensitive to changes in a single variable. Sensitivity analysis is required when differences among alternatives are less obvious and may be to-

“Program managers face tremendous pressure to bring a product into use.”

tally driven by variability of key input factors. The key factors to be tested may include, but are not limited to,

project or program length, volume or quantity and mix of production units, requirements, configurations, assumptions, and discount rates and other economic factors.

#### **STEP 6. DEVELOPING A MIGRATION STRATEGY**

After determining the best alternative, one must develop a sound implementation plan to migrate the “winning strategy” into the program. This plan must incorporate a systematic approach whereby the developer plans to implement the identified drivers and capture the expected benefits. Implementation of the migration strategy will undoubtedly force changes to the program’s plan and budget. If a new tool or process is expected to save money, then those savings should be subtracted from that part of the program budget and reassigned elsewhere as an up-front action.

#### **STEP 7. MONITORING AND ASSESSMENT THROUGH FORMALIZED FEEDBACK**

The final step in developing a business case will be to create metrics to assess progress toward the overall vision. These metrics should be tied to the changes made to the program’s acquisition plan, to provide timely feedback on their success in meeting desired results in performance, schedule, and cost. Performance metrics should stem from the needs and requirements that alternatives are fulfilling, and should address the benefits they are expected to provide. Schedule and cost metrics must also be developed to help ensure programs adhere to planned costs and schedules (Kidwell, 1998; DoD, 1995; GSA, 1998).

Program managers face tremendous pressure to bring a product into use. While it is the program manager who can best provide monitoring input, funding limits and timelines debilitate an aggregate approach to monitoring. Unquestionably, program managers should consider the entire life cycle of the project. But in the present acquisition environment there is little incentive to do this. Program managers are the lynchpin to success, since they hold all of the program-specific information.

Program managers must deliver their programs with complementary benefits first. This is their true priority, but they should also identify real or potential external benefits up the management chain to the program executive officer. That office can then make more informed decisions on the macro benefits. Program managers should consider increasing investment earlier in the program if the business case strongly indicates downstream

savings as a result. Program executive officers can provide the attendant oversight and direction, with a requisite reallocation of funds when it is in DoD's best interest to do so. DoD has made some marginal progress, as historically, program managers did not worry about maintainability and sustainability issues. Now Gansler's revolution in military affairs is mandated through specifications and expectations in our contracts. Acquisition decision makers must shift expectations as M&S technology enables more informed tradeoff decisions against such things as disposal costs. We must include this approach in our business case analysis. This requires a fundamental attitudinal change not only on the part of program managers, but also for the entire acquisition team and DoD.

Monitoring needs to be a truly integrated process, with all elements actively involved. A sharing of analysis, combined with a DoD commitment to maximize and optimize any potential benefits of M&S technology, will bring unprecedented reward—in cheaper, better, stronger products and the associated prudence in managing the public purse.

## **CONCLUSIONS**

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Often, finding the solution to complex technological problems is a game of chance, where there are a limited number of variables but a near limitless combination of these to bring about technological breakthroughs. M&S permits the program manager to experiment with a larger number of possibilities without undue risk. Once the essential data is determined, collected, and then shaped within a model,

the simulations provide a tremendous advantage over traditional methods of trial and error.

The use of M&S in program management is no longer reserved for programs on the cutting edge of technological development, nor is it simply an "experimental tool." Both industry and the government should rely on sound business practices for success. Both should also realize that M&S is an established business tool, and that M&S investment justification should be based on a reasoned cost-benefit analysis.

Unfortunately establishing the cost-benefit relationship of M&S investments can be just as daunting as the management of a program itself. The use of a business case development process to justify M&S development provides a flexible

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yet structured methodology for program managers to weigh alternatives. Business case analysis permits the program manager to justify investment decisions based on traditional discounted cash flow analyses, as a function of externally imposed constraints, and risk reduction. It allows program managers to capture not only those costs and benefits that are internally quantifiable and unquantifiable, but to address potential benefits that may exist external to the program. A disciplined approach to making investment decisions also provides a mechanism for those

outside the program management office to examine and assess investments for broader applicability.

Our research indicates that in a large section of the acquisition community, insufficient rigor is applied to M&S investment justification. We uncovered a variety of tools and references available to program managers for conducting business case analyses. Building a business case not only helps program managers ensure M&S investment is warranted, but serves as a reference for others when trying to make similar investments or as a baseline document that other program managers and offices can use when building investment strategies. Business case analyses also build strong justifications to defend M&S investments and bring rigor and discipline to the program or project management processes. The seven-step procedure identified in the body of this article captures the essence of available guidance, knowledge, and experience and should provide program managers with a starting point when considering M&S investments.

## RECOMMENDATIONS

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Having a clear understanding of the state of development we believe the following recommendations will serve to assist program managers with the development of modeling and simulation investment strategies based on a sound business case development processes.

- Program managers need to be encouraged to add discipline and structure to their M&S justification process. Service leadership must challenge program managers to use business case development methodology to support M&S investment decisions.
- Program managers require ready access to policy and guidelines from the General Services Administration, the Office of the Secretary of Defense, and each service in order to develop successfully a business case justification. We recommend incorporation of documents referenced in this paper into the *Defense Acquisition Deskbook* along with a section to serve as a primer for business case development.
- Program managers and their staff need adequate training in order to properly implement business case-based M&S investment strategy justification. Acquisition curriculum at service schools and the Defense Systems Management College should include business case development familiarization classes.
- Service leadership should capture success stories and publish them in appropriate service and DoD journals, magazines, other publications, and related acquisition Internet sites.



**Dr. C. David Brown** is a member of the Senior Executive Service and presently serves as the Director for Test and Technology for the Army Developmental Test Command, and previously served as the focal point for the Army's application of modeling and simulation techniques to technical test and evaluation. In addition to holding two patents, he has authored numerous technical papers, is a registered professional engineer, a member of the Army Acquisition Corps and is an Army Reserve Colonel assigned to the Army Chief of Staff. He has a doctorate degree in electrical engineering from the University of Delaware, and is also a graduate of the Industrial College of the Armed Forces.

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## ENDNOTES

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1. Quoted by Permission, Brigadier General Michael Hough, USMC, deputy program manager Joint Strike Fighter, during an address to the ICAF Acquisition Class, March 19, 1999.
2. DoD Total Ownership Cost (TOC) is the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and its components.
3. The Grizzly Program is a U.S. Army program. The Grizzly is a complex obstacle breaching system based on the M1 Abrams tank chassis. It is designed to support combined arms maneuver operations.
4. For a short description of each, see GSA's *Information Technology Capital Planning and Investment Guide*.

